

precision pressure gages, controllers and systems



FUSED QUARTZ PRECISION PRESSURE GAGES

features...

- Interchangeable pressure elements
- High resolution, exceptional repeatability
- Wide range
- Useful with any pressure medium
- Faster than mercury manometer or dead-weight tester
- Portable, compact, easy to use
- No restoring torque applied to pressure-sensitive element
- For use in any absolute, differential or gage application

Texas Instruments Precision Pressure Gages utilize the near-perfect elastic properties of fused quartz to provide an instrument that combines extreme accuracy with versatility and unexcelled operating convenience.

Gages consist basically of two parts—the interchangeable capsule containing the fused quartz pressure-sensitive element and the readout instrument. Bourdon tube deflection is measured directly by optical means so that no fragile force balance linkages are required. Optical coupling between pressure sensor and readout eliminates reactive and frictional forces on the sensor, assuring optimum repeatability. Optical

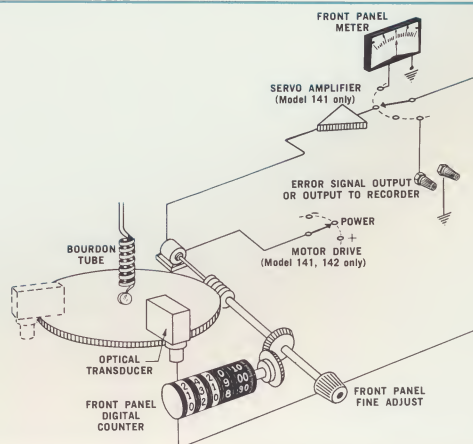
detection also provides a simple, reliable, proportional error signal output for control applications.

Precision Pressure Gages do not require a prepared site, precise leveling or special skill to operate. Accuracy is unaffected by variations in the molecular weight of the gas or vapor. Since neither mercury nor oil is required, problems concerning corrosive media or chemical interaction with the manometric fluid are completely eliminated.

Within their range Precision Pressure Gages can be used in any absolute, gage or differential application requiring precise measurement or sensing of pressure.

how it works...

The optical transducer is mounted on a gear that travels concentrically around the Bourdon tube. In operation the deflection of the pressurized Bourdon tube is found by rotating the gear until the null-indicator reading is zero, i.e. light reflected from the tube mirror falls equally on a pair of balanced photocells. The digital-counter reading representing the deflection of the tube is then multiplied by a scale factor to determine the pressure. A calibration chart is supplied with each capsule.



**Manual Gage
Model 140**

Nulling is accomplished by turning a coarse dial until approximate null position is indicated on a front panel meter. A fine adjustment is then turned to the exact null.



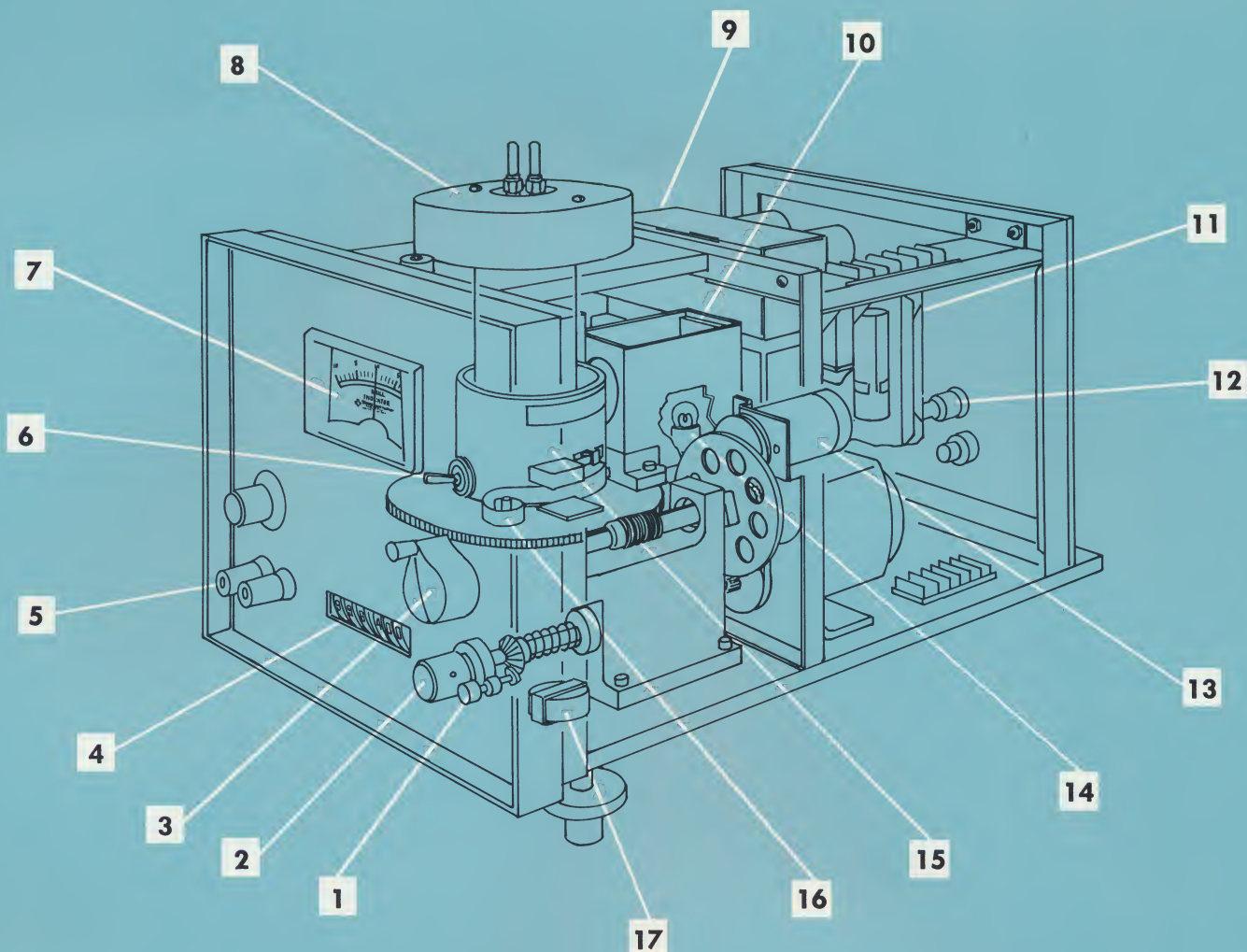
**Servo-Nulling Gage
Model 141**

Nulling is accomplished automatically by a closed-loop, motor-driven servo system. Null position is constantly maintained for minute variations in the pressure being measured. The Servo-Nulling Gage is most versatile in that it can be used in three operating modes: manual-nulling, servo-nulling or output to external recorder.



**Motor-Driven Gage
Model 142**

Coarse nulling is accomplished by a control switch operating a motor drive. Actuating the switch drives the optical transducer to approximate null. When a coarse null is reached, the switch is released and the manual control is used to achieve a precise null.



1. Clutch lock
2. Clutch for "counter set"
3. Manual coarse null adjust (manual model only)
4. Digital counter with high speed nylon geneva transfer
5. Photocell output for recorder
6. Motor drive switch (motor-driven models only)
7. Parallax scale for more accurate manual nulling
8. Thermostatted Bourdon tube heater
9. Servo amplifier

10. Photocell assembly with silicon solar cells
11. Line voltage regulator for input power regulation
12. 110-220 volt lock switching for 50-cps models
13. Tachometer damping for stability
14. Long-life transducer lamp
15. Auxiliary solar cells for direction finding—polarity of error signal
16. Anti-backlash spring loaded gearing
17. Alarm buzzer and automatic servo cutoff for over-travel protection of gear train

high-resolution gage

The gearing on these gages provides an indication of 200,000 counts for 100 degrees of Bourdon tube deflection. Resolution is therefore 1 part in 200,000. Repeatability is twice the resolution or 2 parts in 200,000.

Full-scale slew rate on servo gages is 2.1 minutes. Where the slew rate must be increased, it can be doubled by using a high-resolution gage and a Bourdon tube with twice the range required. For example, a 0-100 psi capsule in a standard gage (resolution 0.001 psi) will track from 0-100 psi in 2.1 minutes. A 200-psi capsule in a high-resolution gage (resolution 0.001 psi) will track 0-100 psi in 1.05 minutes.

micron gage

The gearing on these gages provides an indication of 300,000 counts for 100 degrees of Bourdon tube deflection. Resolution is therefore 1 part in 300,000. When micron gage readout units are used with tube No. 14 (0-300 mm) resolution is 1 micron. Micron gage gearing can also be used to triple the slew rate of standard gages. Repeatability of manual and motor-driven gages equipped with the optional micron gage gearing is 2 parts in 300,000. Repeatability of servo gages equipped with micron gage gearing is 3 parts in 300,000. All manual, motor-drive or servo-nulling gages can be equipped with either high-resolution or micron gage gearing.

specifications

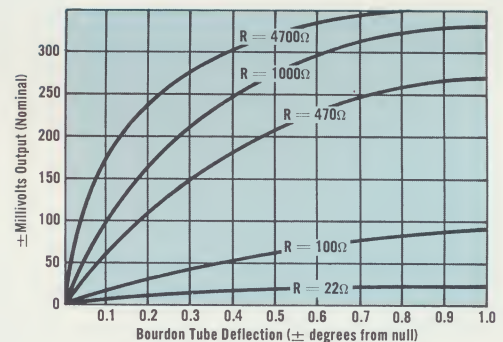
	Model 140	Model 141	Model 142
Resolution* (% of full scale)			
Standard Readout		0.001	
High-Resolution Readout		0.0005	
Micron Readout		0.0003	
Repeatability (% of full scale)			
Standard Readout	0.002	0.002	0.002
High-Resolution Readout	0.001	0.0017	0.001
Micron Readout	0.0006	0.0015	0.0006
Readout Range*			
Degrees of Bourdon Tube Deflection		100°	
Operational Temperature Range		50°-100°F (10°-38°C)	
Temperature Sensitivity			
Thermostat Heater "On" and Set to 120°F (49°C)		less than .001% of reading per degree F ambient change	
Thermostat Heater "Off"		0.008% of reading per degree F ambient change	
Tilt (level) Sensitivity		max 0.0005% of full scale per degree of tilt	
Calibration Accuracy (absolute)			
		0.015% of reading plus repeatability over range 7-500 psi (376-25,000 mm Hg)	
		0.002 in. Hg (0.05 mm) plus repeatability over range 1-15 in. Hg (25-376 mm)	
		8 μ of Hg plus repeatability over range 0-1 in. Hg (0-25 mm)	
Power Requirements			
60 cps Models	105-125 v-ac 110 w	105-125 v-ac 130 w	105-125 v-ac 115 w
50 cps Models	105-250 v-ac 110 w	105-250 v-ac 130 w	105-250 v-ac 115 w
Slew Rate (100° Bourdon Tube Deflection)	45 sec	2.1 min.**	2.1 min.
Available Torque on Fine Null Adjust—Servo Model		1 in. oz	
Number of 360° Revolutions of Fine Null Adjust for 100° Bourdon Tube Deflection			
Standard Readout		1000	
High-Resolution Readout		counter makes 1000 revolutions	
Micron Readout		counter makes 2000 revolutions	
		counter makes 3000 revolutions	
Dimensions (inches over-all)			
Table-Top	10 $\frac{1}{8}$ ×12×10 $\frac{1}{8}$	10 $\frac{1}{8}$ ×15 $\frac{3}{4}$ ×10 $\frac{1}{8}$	10 $\frac{1}{8}$ ×12×10 $\frac{1}{8}$
Rack-Mount	19×14×15	19×14×15 $\frac{1}{2}$	19×14×15 $\frac{1}{2}$
Approximate Weight	20 lb	30 lb	22 lb
Color—All Models		beige and brown (other colors optional)	

*See Bourdon Tube Table for Pressure Equivalents

**Slew rate can be increased by using High-Resolution or Micron Gearing

Output to External Recorder or Control Circuits

Silicon solar cells in the optical nulling system are wide enough so that, at null, pressure variations causing up to $\pm 0.5^\circ$ of Bourdon tube deflection will produce an analog output signal equivalent to $\pm 1^\circ$ of counter reading. The range over which this signal is linear and its magnitude will depend on solar cell loading. By monitoring this signal on a sensitive potentiometer recorder such as the *servo/riter*® extremely high resolution can be obtained over a small portion of the pressure range. For recording over the entire range of the Pressure Capsule, the retransmitting potentiometer option may be used.



FUSED QUARTZ PRESSURE CAPSULES

- Unaffected by corrosive gases
- Least hysteresis, fatigue or creep of any known material
- Fast dynamic response
- Small, constant volume

The high degree of accuracy of the Precision Pressure Gage is attributable to the fused quartz Bourdon tube. The low internal viscosity of fused quartz makes it the most perfectly elastic material known. Bourdon tubes made of fused quartz exhibit lower hysteresis, creep or fatigue than tubes made of any other known material. In addition to having good temperature properties, fused quartz is chemically inert to most corrosive gases, vapors or liquids at ordinary temperatures.

The physical dimensions of the Bourdon tube, i.e. radius, number of turns, wall thickness, and tubing dimensions, have been selected so that Bourdon tubes will rotate 100 degrees for maximum rated pressures up to 200 psi (10,000 mm Hg). The Bourdon tube is dimensionally stabilized by an axial quartz rod attached to the free end. This rod rotates on torsional quartz hinges. Hinges are protected against breakage by shock-absorbing quartz helical springs.

Pressure Capsules consist of a fused quartz Bourdon tube installed in a cylindrical envelope. Each is designed to enable the Pressure Capsule to fit a particular type of application. All Pressure Capsules can be used interchangeably in any readout unit.

For applications requiring pressure measurements on liquids, the Bourdon tube and/or the surrounding space in the tube can be filled with liquid. Liquids used in the reference space must be transparent. Also, the optical system must be modified to compensate for the index of refraction of the liquid used. Head correction for a liquid system is simply effected by zeroing the digital counter with the liquid head on the tube.

temperature characteristics

The thermoelastic modulus of quartz is a negative 13 parts per 100,000 per degree centigrade temperature change. As temperature increases, Bourdon tubes become stronger. All TI Precision Pressure Gages are equipped with a thermostatted temperature bath. Thermostats will maintain Bourdon tube temperature to $\pm 0.5^\circ\text{C}$ over a $10^\circ\text{--}38^\circ\text{C}$ ($50^\circ\text{--}100^\circ\text{F}$) ambient operating range. Bakeout temperature on all Pressure Capsules is 250°F (121°C) unless higher temperatures are indicated.

properties of fused quartz

Fused quartz is made by heating high-purity, naturally occurring quartz crystals to a sufficiently high temperature to produce an amorphous condition. Most acids, metals, chlorine, and bromine are unreactive with fused quartz at ordinary temperatures. Fused quartz has an extremely low

coefficient of thermal expansion equal to 1/34 that of copper, 1/17 of platinum, 1/9 of tungsten, and 1/7 of borosilicate glass. The low expansion imparts a high thermal shock resistance. This makes it possible to subject fused silica to extremely great temperature gradients and heating rates.



dynamic characteristics

Because of the extremely low internal viscosity of fused quartz, Bourdon tubes are virtually undamped. By filling the space surrounding the Bourdon tube with a transparent, viscous fluid such as clear silicone oil, any degree of damping can be achieved. Frequency response in the "output to external recorder mode" is 0–50 cps, depending on the sensitivity of the Bourdon tube. In the recorder mode, response is flat over any $\pm 0.5\%$ of full-scale segment of the range. In the servo mode of operation, pressure frequency response is dependent on the 3-cps response of the servo amplifier, and the slew rate.

Physical Properties of Clear Fused Quartz

Compressive Strength	160,000 psi
Tensile Strength	7,000 psi
Coefficient of Thermal Expansion ($20^\circ\text{--}320^\circ\text{C}$ avg)	0.55×10^{-6} cm/cm/ $^\circ\text{C}$
Thermal Conductivity	0.0033 g cal/cm ² /sec/ $^\circ\text{C}$ /cm
Softening Point	(approx) 1670°C
Annealing Point	(approx) 1140°C
Thermoelastic Modulus	$1.3 \times 10^{-4}/^\circ\text{C}$

FUSED QUARTZ BOURDON TUBE CAPSULES

type 1

STANDARD - OPEN REFERENCE PORT The reference space surrounding the Bourdon tube is open so that the capsule can be connected to a vacuum pump for absolute measurements or left open to the atmosphere for gage measurements. The optical-quality outer Pyrex cylinder will withstand 100 psi (5000 mm Hg), permitting use of this capsule in differential applications to 100 psi. Available in all tube numbers.

type 2

STANDARD - PERMANENTLY EVACUATED The Bourdon tube is evacuated to less than 0.1μ and fused closed to assure a permanent leak-tight reference vacuum. In use, pressure is applied to the outside of the Bourdon tube. Ranges are limited by the 100-psi (5171 mm Hg) strength of the outer Pyrex cylinder. Available in all tube numbers except 7, 10 and 16.

type 3

HIGH LINE PRESSURE — ALUMINUM Employs an aluminum outer cylinder with a thick sapphire window to withstand pressures up to 500 psi (25,857 mm Hg). The window permits viewing only 25 degrees of mirror rotation, limiting measurements to 25% of the range of the Bourdon tube. The reference port can be evacuated or left open to the atmosphere for gage or absolute measurements. Available in all tube numbers except 9B, 11B and 11C.

type 4

HIGH LINE PRESSURE — STAINLESS STEEL Outer cylinder is made of stainless steel capable of containing 2000 psi. Window limits view to 25 degrees of mirror deflection; therefore, measurements may be made over 25% of normal Bourdon tube range. The reference port can be evacuated or left open to the atmosphere for gage or absolute measurements. Available in all tube numbers except 9B, 11B and 11C.

type 5

BAKEABLE - OPEN REFERENCE PORT Constructed entirely of Pyrex with all joints fused. Will withstand bakeout temperatures to 400°C . Pressure and the reference ports terminate in $\frac{1}{4}$ -inch Pyrex tubing, enabling them to be permanently fused into laboratory glass systems. The reference port is open to the atmosphere for gage measurements or may be connected to a vacuum pump for absolute measurements. The outer Pyrex envelope will withstand 50 in. Hg (1250 mm Hg), permitting use of the capsule in differential applications to 50 in. Hg. Available in all tube numbers.

type 6

BAKEABLE—PERMANENTLY EVACUATED Identical in construction to the Type 5 except that the envelope surrounding the Bourdon tube is evacuated to less than 0.1μ and fused closed for a permanent leak-tight reference vacuum. Available in all tube numbers except 3, 6, 7, 10, 15, and 16.

type 7

HIGH TEMPERATURE - OPEN REFERENCE PORT Identical in construction to Type 5 except that the outer envelope is fused quartz, being able to withstand 530°C (bakeout or continuous operation). Since geared readout units must be operated at lower than 130°F , Type 7 capsules are normally used in the "pressure-restoring-to-null" mode in applications requiring continuous operation at high temperatures. Available in all tube numbers.

type 8

HIGH TEMPERATURE - PERMANENTLY EVACUATED Identical in construction to Type 6 bakeable capsules except that the outer envelope is of fused quartz and will withstand temperatures to 530°C . Available in all tube numbers except 3, 6, 7, 10, 15, and 16.

specifications

Internal Bourdon Tube Volume (to base of pressure fitting, nominal)	0.03 cu in. (0.5 cc)
Capsule Volume (nominal)	8.0 cu in. (132 cc)
Volume Change of Bourdon Tube for Max Pressure Change	<1 part in 10^{10}
Capsule Dimensions (over-all)	$6" \times 2\frac{1}{2}"$ ($15\frac{1}{4} \times 6\frac{1}{4}$ cm)
Helium Diffusion Rate	approx 2.5×10^{-8} cc/sec/mm Hg D
Natural Undamped Resonant Frequency	approx 20-100 cps (depends on max rated pressure)

*Linearity (flatness) nominally 1%

*Higher linearity over small portions of the total range is optional

Hysteresis	$<$ gage resolution
Fatigue	$<$ gage resolution
Reference Vacuum in Permanently Evacuated Capsule	$<0.1 \mu$
Leak Rate	

Type 1, 3, 4

Bourdon Tube Port	$<10^{-11}$ cc/hr
Reference Port	$<3 \mu/\text{hr}$ (after outgassing)

Type 2, 6, 8

Sealed Bourdon Tube	virtually zero
Reference Port	$<3 \mu/\text{hr}$ (after outgassing)

Type 5, 6

virtually zero

pressure ranges

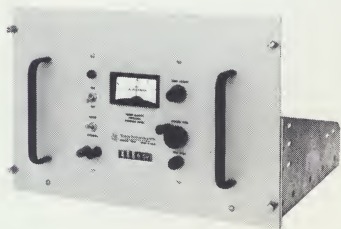
Tube No.	Pressure Range 100° Bourdon Tube Deflection					Minimum Resolution in Standard Gage		Repeatability in Standard Gage	
	In. Hg	In. H ₂ O	psi	mm Hg	Mb	In. Hg	mm Hg	In. Hg	mm Hg
11A	0-10	0-138	0-5	0-259		0.0001	0.003	0.0002	0.006
14	0-12	0-166	0-6	0-300		0.0001	0.003	0.0002	0.006
11B	10-20	138-276	5-10	259-517		0.0001	0.003	0.0002	0.006
13	0-20	0-276	0-10	0-517		0.0002	0.005	0.0004	0.010
11C	20-30	276-414	10-15	517-776	678-1016	0.0001	0.003	0.0002	0.006
9	—	—	—	—	1080	0.01 (mb)	—	0.02 (mb)	—
9B	—	—	—	—	1080	0.01 (mb)	—	0.02 (mb)	—
1	0-32	0-434	0-15.7	0-813	1084	0.0003	0.008	0.0006	0.016
8	0-39	0-534	0-19	0-1000	1321	0.0004	0.010	0.0008	0.020
2	0-50	0-678	0-24	0-1270	1693	0.0005	0.013	0.0010	0.026
3	0-100	0-1357	0-49	0-2540	3386	0.0010	0.025	0.0020	0.050
15	0-125	0-1695	0-61	0-3175	4233	0.0012	0.032	0.0024	0.064
6	0-204	0-2763	0-100	0-5171	6908	0.001 psi	0.052	0.002 psi	0.104
7	0-407	0-5526	0-200	0-10,342	13,783	0.002 psi	0.100	0.004 psi	0.200
16	0-612	0-8289	0-300	0-15,543	20,725	0.005 psi	0.259	0.010 psi	0.510
10	0-1018	0-13,814	0-500	0-25,857	34,474	0.020 psi	1.000	0.040 psi	2.000
12	Custom Range		0-10 in. Hg min (0-259 mm)		0-500 psi max (0-25,857 mm Hg)				

*Direct reading to 0.1 mb over barometric pressure range

accessories

relay rack mounting

Designed to fit all 19-inch by 21-inch deep relay racks. Gage assembly is mounted on roll-out slides for easy accessibility. Panel height 17½ inches.



switch-closure digital counter

For applications requiring readout to a remote indicator or tape printer, the standard counter is replaced with a counter having 10 switch closures on each of the last four wheels. Since the unit wheel on this counter has only 10 divisions, readout resolution is 1 part in 10,000. For use in standard geared servo model only. Switch-closure capacity: 110 v-ac, 250 ma; 110 v-dc, 50 ma. Switch-closure counter assembly includes a detent mechanism to minimize switch ambiguity at non-integral pressures. This mechanism consists of a solenoid-actuated plunger which drives a star detent wheel connected to the counter. The solenoid-drive circuit is designed so that the solenoid is actuated only when the pressure is within $\pm 0.005\%$ (of full scale) of true null.

high pressure metallic bourdon tubes

For pressure measurements from 500 to 20,000 psi (35-1350 atmospheres). Interchangeable capsules can be used in all model Precision Pressure Gage Readout Units. Write for bulletin.



weatherproof carrying case

All aluminum carrying case provides complete accessibility without removing gage from base. Size: 19 inches by 13½ inches by 12½ inches. Weight: 10 pounds.

retransmitting potentiometer

Provides a resistance signal throughout the 100 degrees of Bourdon tube deflection range. Employs a 10-turn, 0.1% potentiometer with total resistances available of 50 to 200,000 ohms. Retransmitting potentiometers are available on servo model gages only.

in-line digital display

A visual display unit for use with gages equipped with a switch-closure counter. Will display digits from 0000 to 9999. Figures are 7/8-inch high. Operates from 110 volts, 50-60 cps. Includes 8 feet of cable for connecting to gage. Additional cable optional. Size: 10 inches by 8½ inches by 4½ inches. Weight: 3 pounds.

hardwood carrying case

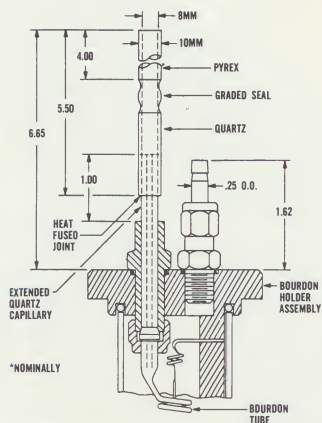
Natural ash finish, polyurethane foam-lined case protects pressure gage during transit. Size: 20 inches by 14½ inches by 13½ inches. Weight: 25 pounds. Carrying case for Bourdon tube—natural ash finish, polyurethane foam-lined with provisions for 4 Bourdon tubes. Size: 10 inches by 10 inches by 10 inches. Weight: 6 pounds.

custom accessories

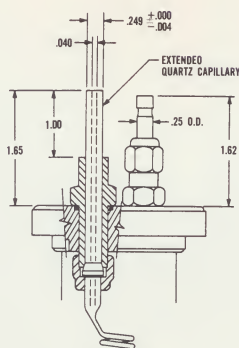
A wide variety of custom accessories such as shaft encoders, Bourdon tube temperature monitor, and battery operation can be incorporated in Precision Pressure Gages. Send details concerning your requirements for a quotation.

special bourdon tube fittings

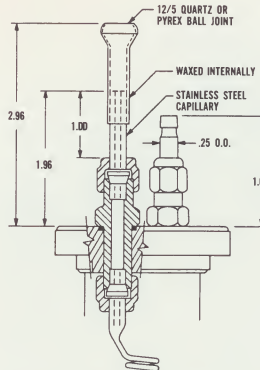
Special fittings are available for the Bourdon tube capsules. Those shown below and the optional overpressure relief valve can be installed on any Type 1, 2, 3, or 4 capsules. Optional AN pressure fittings can be installed on the capsule inlet; a 400-6-4AN to Swagelok® adaptor is recommended for the Bourdon tube port.



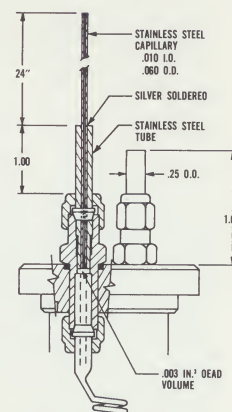
QP Graded Seal, Quartz to Pyrex Bourdon Tube Extension



Extended Fused Quartz Fitting



BV Ball Vacuum Fitting



C Detail Stainless Steel Capillary Fitting Adaptor

PRECISION PRESSURE CONTROL

- Automatic control
- High resolution, repeatability
- Motorized digital input
- Operationally fast
- Rapid settling time
- Low overshoot
- Table mount or console systems
- Compact, easy to use

Pressure Control Systems include two basic units: a pressure generator and a very precise measuring and/or readout instrument. In TI Pressure Control Systems the sensor is a fused quartz Precision Pressure Gage. The pressure generator is a separately packaged servo regulator unit or a servo regular assembly installed in the Gage-Controller combination unit. In either case, control is effected by continuously correcting the regulator output with an extremely sensitive servo system taking its error signal from the precision pressure photocell assembly.

combination gage-controllers

- Flight Simulation Systems
- Transducer Calibration
- Precision Process Control
- Air Data Computer Calibration
- Environmental Chamber Control
- Quality Control

Gage-Controllers (or Servo Low Pressure Controllers operating in conjunction with a Precision Pressure Gage) can be used to provide a very precisely controlled pressure in dead-end or low-flow pneumatic systems. When used with precision diaphragm valves, these systems can be used to control large-volume liquid or gas flow very accurately.

Model 156 table or rack-mount units are identical in performance to Model 155 console systems. They differ only in that they require external pressure and vacuum sources and the pneumatic connection must be manually switched from the control to the measuring mode of operation. Rack-mount units include chassis slide assemblies and all mounting hardware. The materials in contact with the gas are brass, stainless steel, neoprene, and nylon.

How They Work

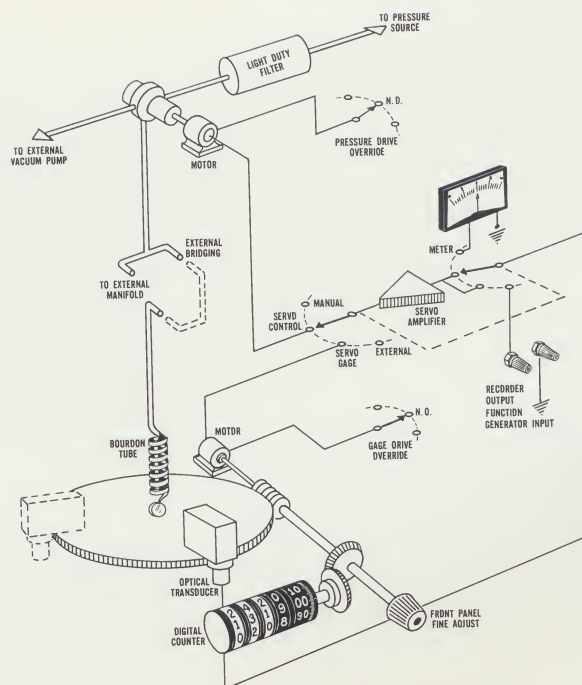
In the control mode of operation the Bourdon tube deflection angle associated with the desired pressure is preset with the gage drive and/or manual adjust controls. "Dialing in" a new angle unbalances the photocells to create an error signal which,

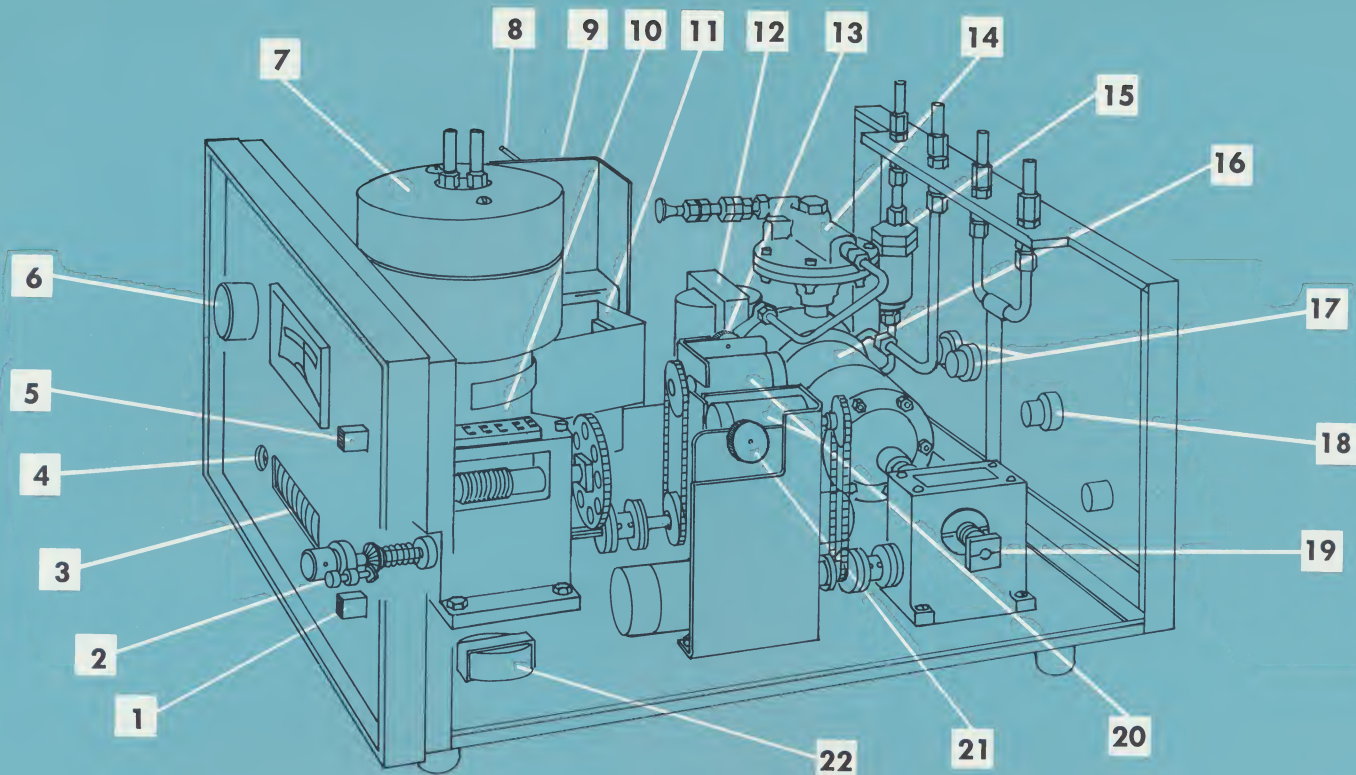
after amplification, activates a servo motor to drive the precision regulator. The regulator adjusts the output pressure, which is fed back to the Bourdon tube to cancel the error signal when the pressure corresponds to the angle "dialed in". The panel meter deflection indicates the direction the regulator (and pressure) is driving.

The gage drive switch changes the position of the photocell assembly. Since the photocell error signal is connected to the pressure-regulating loop, the regulator will approximately track the repositioning photocell assembly so that the system will be at the set pressure shortly after the gage drive switch is released.

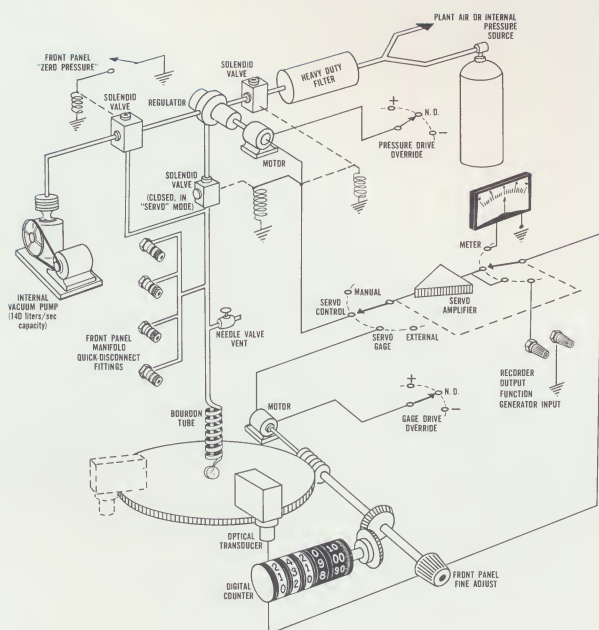
The pressure drive switch overrides the photocell error signal to drive the pressure regulator, thereby changing the pressure without changing the position of the photocell assembly. It is used to exercise the transducer connected to the output pressure to check hysteresis in the transducer.

By connecting a low frequency function generator to the unit, an a-c signal can be superimposed on the d-c error signal. In this mode of operation the system can generate continuous sine, ramp or square wave pressure functions up to 3 cps, depending on the pressure amplitude.





- | | | |
|--|--|---|
| 1. Gage drive switch | 10. Auxiliary solar cells for direction finding—polarity of error signal | 17. Function generator input (photo-cell output) |
| 2. Clutch for "counter set" | 11. Photocell assembly with silicon solar cells | 18. 110-220 volt lock switching for 50-cps operation |
| 3. Digital counter with high speed nylon geneva transfer | 12. Lamp filament voltage regulator | 19. Regulator mechanical stop to prevent accidental overpressure |
| 4. Zero adjust | 13. Damping control—gage | 20. Tachometer damping for stability |
| 5. Pressure drive switch | 14. Low flow controller | 21. Damping control—controller |
| 6. Mode selector switch | 15. Input air filter | 22. Alarm buzzer and automatic servo cutoff for overtravel protection of gear train |
| 7. Thermostatted Bourdon tube heater | 16. Precision output regulator | |
| 8. Gain control | | |
| 9. Servo amplifier | | |



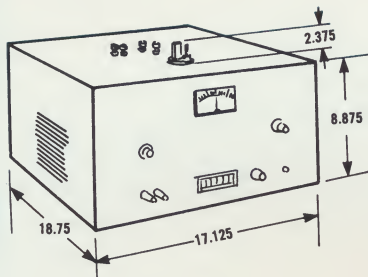
MODEL 155 GAGE-CONTROLLER

specifications – models 155 and 156

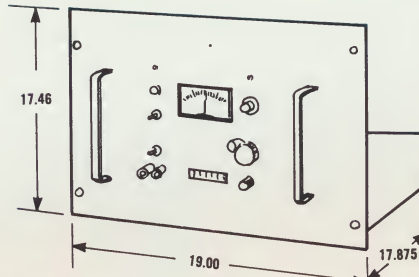
Pressure Range	A	B
Measurement Mode	0-50 in. Hg A*	0-125 in. Hg A*
Control Mode	0.5-50 in. Hg A	0.5-125 in. Hg A
Output Control "Sensitivity"	0.0005 in. Hg	
Resolution of Gage Counter at Set Point	0.0005 in. Hg	0.001 in. Hg
Repeatability of Gage at Set Point	0.001 in. Hg	0.002 in. Hg
Slew Rate		
Measurement Mode	1 min. f/s	2.1 min. f/s
Control Mode	50 in. Hg/min. into 100 cu in. volume	

Settling Time for Full Scale Pressure Change, 100 cu in. Volume Load	A	B
	15 sec max	
Max Leak Rate for Rated Control	.02 scfm	
Max Overshoot with 100 cu in. Volume Load	0.01% of f/s (can be reduced to zero by adjusting damping of servo regulator)	
Min Input Pressure Requirements (clean dry nitrogen)	30 psig	60 psig
Absolute Accuracy	0.015% of reading plus repeatability or 0.002 in. Hg. plus repeatability, whichever is greater (calibration chart supplied with each instrument)	
Ambient Operating Temperature Range (no temperature corrections necessary)	50°-100°F (error less than the rated absolute accuracy)	

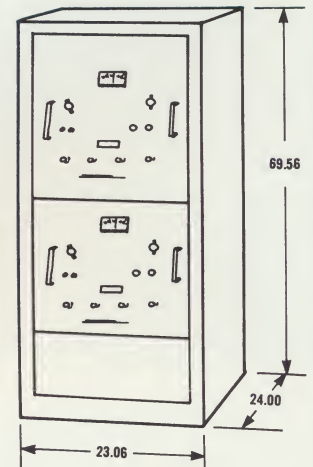
*Supplied with permanently evacuated Bourdon tube assembly unless otherwise specified. For air data test applications specify open reference port on 125 in. Hg Pressure Capsule and permanently evacuated Bourdon tube on 0-50 in. Hg capsule.
Secondary direct reading altimeter and/or air speed indicator can be installed on any unit at optional extra cost. Please specify manufacturer's type and model number when requesting quotation on addition of secondary gages.



**MODEL 156
TYPE 1**



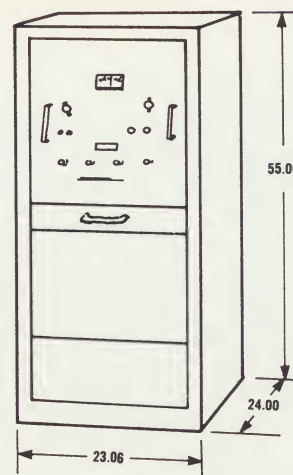
**MODEL 156
TYPE 2**



**MODEL 155
TYPE 2 OR 3**

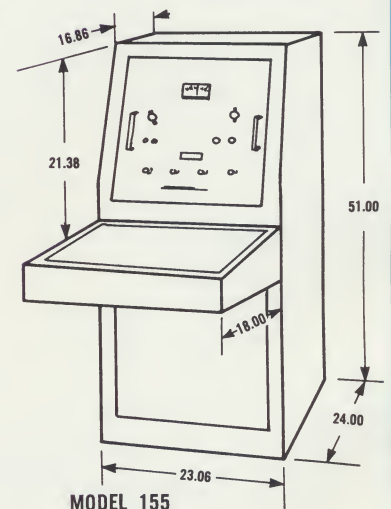
case types available

	Model 155	Model 156
Type 1	Desk console on shock-mounted casters, single unit Weight 250 lb	Table top Weight 50 lb
Type 2	Relay rack, single unit (with room for future addition of second unit) Weight 275 lb	Panel mount Weight 50 lb
Type 3	Relay rack, includes two units, one vacuum pump Weight 325 lb	—
Type 4	Relay rack, single unit with roll-out desk and shock-mounted casters Weight 240 lb	—
Color	TI brown and beige, other colors optional	
Power Requirements	110 v, 60 cps or 110 v-220 v, 50 cps Model 156, Type 1, Type 2-150 w Model 155, Type 1, Type 2-1050 w; Type 3-1200 w	



**MODEL 155
TYPE 4**

all dimensions in inches



**MODEL 155
TYPE 1**

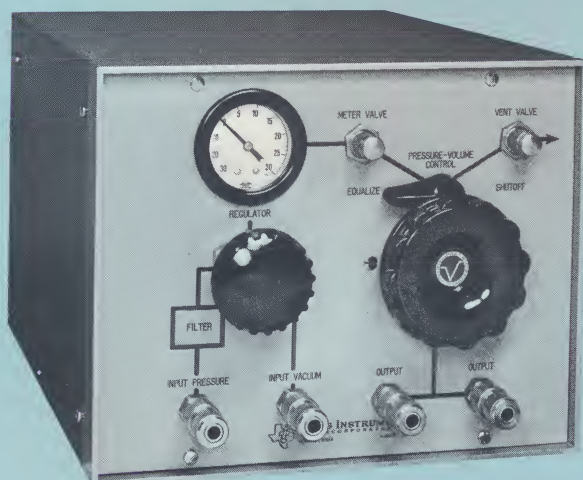
servo low pressure controller model LPC 100

When used with the Texas Instruments Fused Quartz Precision Pressure Gage as the pressure sensing element, the Precision Low Pressure Servo Controller will regulate the pressure in systems from 0.5 in. Hg to 100 in. Hg absolute (12-2540 mm).

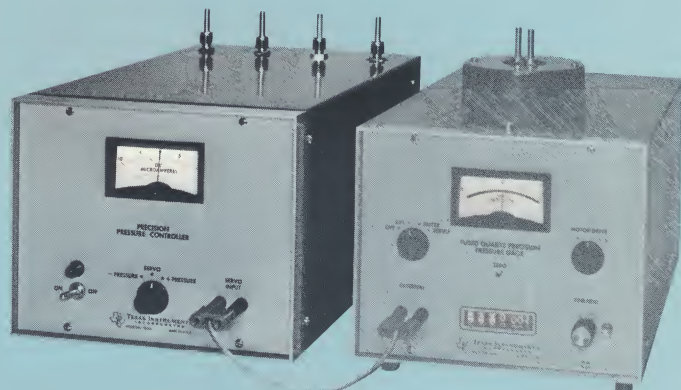
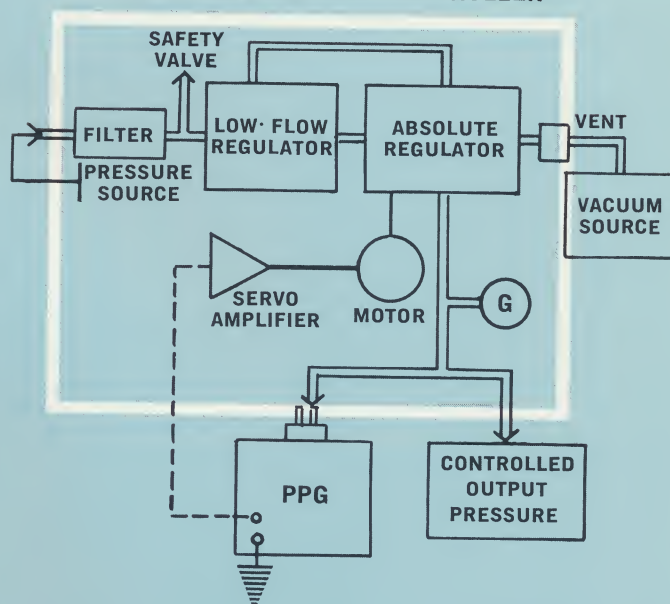
LPC 100 controllers may be used in dead-end or low-flow applications. Maximum flow is 0.02 scfm with atmospheric supply pressure. Atmospheric or plant air may be used for the supply, and a vacuum pump is required to control sub-atmospheric pressures. The controller pressure is unaffected by small supply pressure variations. Servo controllers are equipped with a servo-override switch to drive the pressure independent of error signal for use with manometers, dead-weight testers, pressure transducers, etc. The materials in contact with the gas are brass, copper, stainless steel, neoprene, and nylon.

specifications

Supply Pressure vacuum and 60 psig
Output Range 0.5-100 in. Hg A
Output Regulation 0.0005 in. Hg
Slew Rate 50 in. Hg (1250 mm) in 1 min.
Input Signal Required .. $\pm 5 \mu v$ into 10K load
Maximum Cycling Rate .. 3 cps
Power Requirements ... 110 v, 60 cps; 220-110 v, 50 cps; 30 w
Operating
Temperature Range .. 32°-110°F (0°-43°C)
Dimensions 10"×9"×12"
Weight 25 lbs



SERVO LOW PRESSURE CONTROLLER



manual controller model PCS

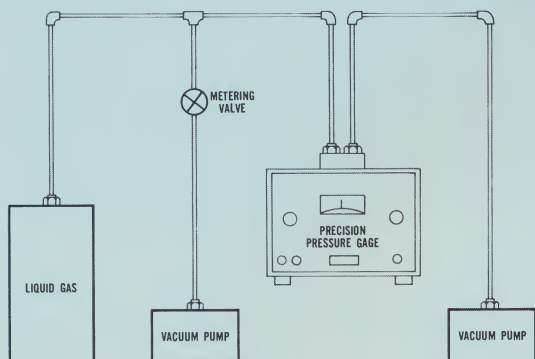
Designed specifically for use in precision pressure calibration systems, the Manual Controller can be used in any application which calls for a very precise control of pressure. All set-up and control functions are manually operated. The controller can be used with all model gages in dead-end or low-flow systems. When used with the Precision Pressure Gage, the desired pressure is dialed in the gage and the controller is adjusted until the meter nulls. Pressure can be adjusted in increments as small as 0.0005 psi or less.

specifications

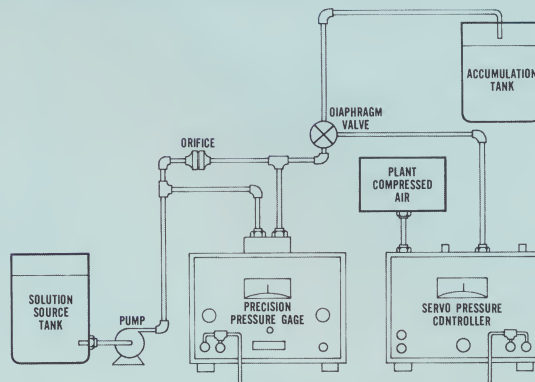
Adjustment Sensitivity — Nonflow Systems 0.0005 psi
(depends on resolution of external precision pressure indicator)
Output Pressure Range — Model PCS 50 0-50 psia
Model PCS 100 0-100 psia
Model PCS 500 0-500 psia
Dimensions 10"×9"×12"
Weight 21 lb

TYPICAL APPLICATIONS

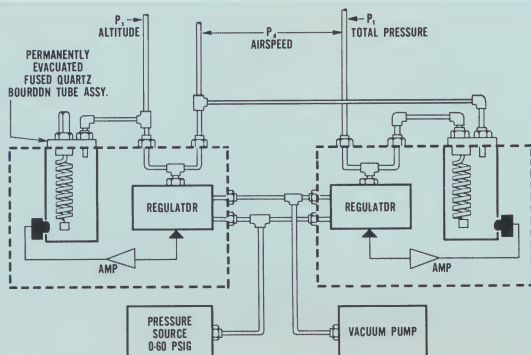
Additional information on these and other applications is available on request



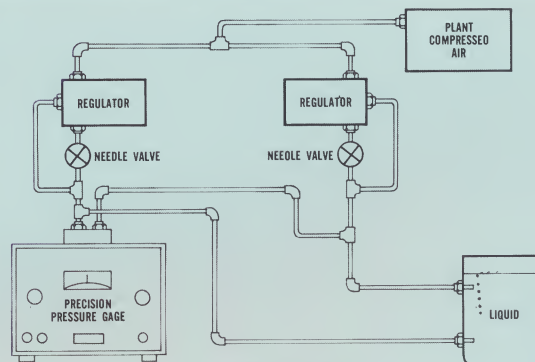
MEASUREMENT OR CONTROL OF CRYOGENIC TEMPERATURE BY GAS VAPOR PRESSURE



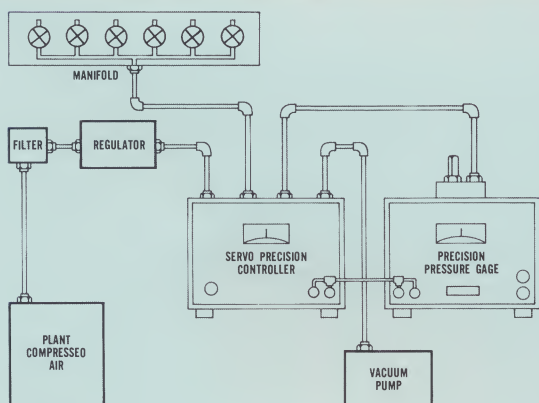
CONSTANT FLOW CONTROL



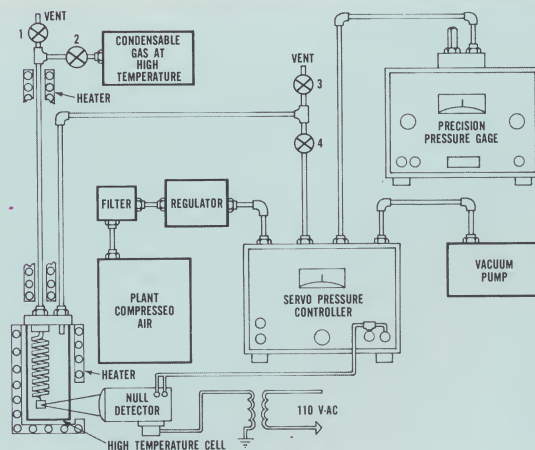
AIR DATA CALIBRATION SYSTEM USING TWO AUTOMATIC PRESSURE SYSTEMS



PURGE BUBBLE SPECIFIC GRAVITY MEASUREMENT



TRANSDUCER CALIBRATION



MEASUREMENT OF PRESSURE ON CONDENSABLE GASES

INDUSTRIAL
PRODUCTS
GROUP



TEXAS INSTRUMENTS
INCORPORATED

APPARATUS DIVISION

P. O. BOX 66027 HOUSTON, TEXAS 77006
118 RUE du RHONE GENEVA, SWITZERLAND



TEXAS INSTRUMENTS
INCORPORATED

P. O. BOX 66027
HOUSTON 6, TEXAS

APPARATUS DIVISION
INDUSTRIAL PRODUCTS GROUP

Scientific Instruments
Product Bulletin P 146
Amended May 16, 1966

PRICE LIST

PRECISION PRESSURE PRODUCTS

To save you time in ordering, this price list may be considered firm and equivalent to a written quotation. You may order directly without a separate quotation. We reserve the right to change prices at any time. If prices are decreased, we guarantee your order will be filled at the lowest prices currently quoted any customer in like circumstances, quality and quantity considered. If prices are increased, we agree to notify you promptly and receive your approval before processing the order.

PRECISION PRESSURE GAGES - BASIC UNITS

Model 140 Precision Pressure Gage

Manual Nulling - price includes one \$500.00
fused quartz Bourdon tube capsule. 50 or 60
cps operation.
Shipping Weight - 23 lbs

Standard Read Out		\$1,800.00
High Resolution Read Out		\$1,925.00
Micron Read Out		\$1,950.00

Model 141 Precision Pressure Gage

Servo Nulling - price includes one \$500.00
fused quartz Bourdon tube capsule. 50 or 60
cps operation.
Shipping Weight - 33 lbs

Standard Read Out		\$2,495.00
High Resolution Read Out		\$2,620.00
Micron Read Out		\$2,645.00

Model 142 Precision Pressure Gage

Motor Driven Nulling - price includes one
\$500.00 fused quartz Bourdon tube capsule.

50 or 60 cps.

Shipping Weight - 25.5 lbs

Standard Read Out	\$1,900.00
High Resolution Read Out	\$2,025.00
Micron Read Out	\$2,050.00

PRECISION PRESSURE GAGE ACCESSORIES

RR - Relay Rack Mounting - All Model Gages

Please add to the basic system price	\$ 125.00
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TC - Thermostated Bourdon Tube Capsule Heater Assembly

Proportional, Controlled Thermostatted
heaters are built into all new Model Gages.
Customer should specify maximum tem-
perature (About 20° F over the maximum
expected ambient). Unless otherwise speci-
fied, Gages will be thermostatted at 110° F,
(44° C)

New Equipment	No Charge
Back Fit on older Model Gages	\$ 250.00

SC - Switch Closure Digital Counter

Please add to the basic system price	\$ 305.00
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D - Detent Mechanism

New Equipment	No Charge
Back Fit on older Model Gages	\$ 110.00

ID - In Line Digital Display Unit

Please add to the basic
system price\$ 268.00

Additional cable available at \$3.10 per foot

RP - Retransmitting Potentiometer

A 10-turn Helipot, Model A series, .1% potentiometer provides a resistance "signal" throughout the entire 100° of Bourdon tube deflection. Mating connector is supplied. Because of mechanical stop limitation only the middle 66.6% of the total resistance specified below is available as resistance change

Please specify total resistance

Resistance (Ohms)	Max. Potentiometer Resolution (% of total resistance)	Max. Voltage (Volts)
50	.031	16
500	.023	50
5,000	.013	160
10,000	.011	230
20,000	.009	320
30,000	.008	390
50,000	.007	500
200,000	.005	1,000

Please add to the basic
system price\$ 163.00

CC - Foam Lined Hardwood Carrying Case

Natural Ash finish
Shipping Weight - 14 lbs

For Model 140, 142\$ 65.00

For Model 141\$ 85.00

AC - Weather Proof Aluminum Carrying Case

Size 19" x 13 1/2" x 12 1/2" Installation is such that all parts of the gage are completely accessible.

Net Weight - 10 lbs Shipping Weight - 12 lbs

Price\$ 375.00

Operation and Instruction Manual

One copy furnished with each Precision Pressure Gage. Additional copies

Price, each\$ 5.00

FUSED QUARTZ BOURDON TUBE ELEMENTS

Bourdon Tube Elements are available in the following capsule types:

Type 1 - Standard Capsule - Both ports open.

Type 2 - Standard Capsule - Permanently evacuated Bourdon tube.

Type 3 - High Static Pressure (500 PSI) - Aluminum capsule.
Both ports open.

Type 4 - High Static Pressure (4000 PSI) - Stainless steel capsule
Both ports open.

Type 5 - Bakeable High Temperature Vycor Capsule (530° C)-
Both ports open.

Type 6 - Bakeable High Temperature Vycor Capsule (530° C) -
Permanently evacuated reference port.

For complete description, please see Bulletin S-141A

STANDARD AND HIGH STATIC PRESSURE BOURDON TUBE ASSEMBLIES

For complete description of these tubes numbers, see Page 6 of Bulletin S 141 A

Tube No.	Type 1	Type 2	Type 3	Type 4
	Open Standard Capsule	Sealed Standard Capsule	500 psi Aluminum Capsule	2000 psi Stainless Steel Capsule
1	\$500.00	\$500.00	\$625.00	\$685.00
2	\$500.00	\$500.00	\$625.00	\$685.00
3	\$500.00	\$500.00	\$625.00	\$685.00
6	\$500.00	\$500.00	\$625.00	\$685.00
7	\$500.00	Not available	\$625.00	\$685.00
8	\$500.00	\$500.00	\$625.00	\$685.00
9	\$500.00	\$500.00	\$625.00	\$685.00
9b	\$585.00	\$585.00	Not available	Not available
10	\$500.00	Not available	\$625.00	\$685.00
11A	\$685.00	\$685.00	\$810.00	\$870.00
11B	\$685.00	\$685.00	Not available	Not Available
11C	\$685.00	\$685.00	Not available	Not available
12	\$685.00	\$685.00	\$810.00	\$870.00
13	\$500.00	\$500.00	\$625.00	\$685.00
14	\$685.00	\$685.00	\$810.00	\$870.00
15	\$500.00	\$500.00	\$625.00	\$685.00
16	\$500.00	Not available	\$625.00	\$685.00

Shipping Weight - 3 lbs

BAKEABLE HIGH TEMPERATURE BOURDON TUBE ASSEMBLIES

Tube No.	d	Type 5	Type 6
		400°C	400°C
		Open Vycor Capsule	Sealed Vycor Capsule
1		\$685.00	\$685.00
2		\$685.00	\$685.00
3		\$685.00	Not available
6		\$685.00	Not available
7		\$685.00	Not available
8		\$685.00	\$685.00
9		\$685.00	\$685.00
9 b		\$770.00	\$770.00
10		\$808.00	Not available
11A		\$870.00	\$870.00
11B		\$870.00	\$870.00
11C		\$870.00	\$870.00
12		\$870.00	\$870.00
13		\$685.00	\$685.00
14		\$870.00	\$870.00
15		\$685.00	Not available
16		\$685.00	Not available

SPECIAL BOURDON TUBE CAPSULES

Barometric Bourdon Tube Elements - Tube 9b

Bourdon tube is permanently evacuated and sealed. Barometric tubes have a calibration factor of 10,000 millibars per degree of rotation over any customer specified 100 millibar segment of the barometric pressure range. Although tubes have a resolution of .01 mb, gages equipped with this tube are direct reading to .1mb over the selected range.

High Sensitivity Bourdon Tube Elements - Tubes 11A, 11B, 11C

The Hi-Sensitivity Bourdon tube is designed to rotate 300° for 15 PSI pressure range. Limitation on the read out assembly requires special location of the mirror so the tube has to be designed to operate over one of the following ranges:

0 - 5 PSI, 5 - 10 PSI, or 10 - 15 PSI

Note: Over the 5 - 10 and 10 - 15 PSI ranges, the mirror position is such that the gage read out will not zero for zero pressure differential. All high sensitivity capsules will withstand one full atmosphere of pressure differential.

Special Range Bourdon Tube Capsules - Tube 12

Where the application calls for a maximum rated pressure that is different than that of the pressure capsules listed, customer may specify the maximum rated pressure (up to 500 PSI) on custom designed Bourdon tube assemblies.

Tubes will be designed to have a maximum of 100° of tube rotation at any specified pressure between 5 and 200 PSI (or equivalent). For pressure over 200 PSI and less than 500 PSI, tube will be designed to have a rotation (proportional) between 100° and 25°.

Liquid Filled Bourdon Tubes (For Hydraulic Pressure Measurements)

Most Bourdon tubes can be filled with customer specified (or supplied) fluid, such as water, oil, Dow silicone, etc. Price applies to all simply available fluids. Exotic or rare fluids are optionally extra.

Note: Gages so modified can be used without liquid with no degradation in performance in the nulling mode of operation in gas measurement applications.

Please add to the basic system
price or to the base price of the
Bourdon tube element\$ 75.00

BOURDON TUBE CAPSULE ACCESSORIES

Special Pressure fittings and accessories for special applications

QP - Extended Pyrex Tubing graded
seal from fused quartz to pyrex

Please add to basic system
price or to the base price of the
Bourdon tube element\$ 47.00

E - Extended Fused Quartz Tubing

Please add to the basic system
price or to the base price of the
Bourdon tube element\$ 15.00

BVF - Fused Quartz Male Ball Vacuum Fitting

12/5 ball fitting is fused to the extended
quartz tubing.

Please add to the system price
or to the base price of the Bourdon
tube\$ 30.00

C - Capillary Pressure Fitting

Please add to the system price or to
base price of the Bourdon tube\$ 50.00

SV - Overpressure Safety Relief Valve

Bourdon tubes are designed to withstand 125%
of maximum pressure overpressure at pressures
under 100 PSI and 150% of maximum pressure over-
pressure above 100 PSI

Over pressure relief valve is designed to protect the Bourdon tube against breakage at accidental higher over pressure. It is installed on the Bourdon tube or capsule port depending on whether the tube is open or sealed.

The safety relief valve extends overall height of the Bourdon tube capsule by 1 1/2".

Please add to the system price or to the base price of the Bourdon tube\$ 67.00

AN - AN Pressure Fittings

AN pressure fittings can only be installed on the capsule side of the Bourdon tube assembly. An AN to swage lock adaptor is recommended for applications requiring an AN fitting on the Bourdon tube side of the capsule. Stainless steel AN to swage lock adaptor for Bourdon tube port (1/4" type, 400-6-4AN).

Please add to the system price or to the base price of the Bourdon tube\$ 5.00

AN fitting on capsule port (1/4" type, 400-61-4AN), add to the system price or to the base price of the Bourdon tube\$ 15.00

AF - Air Filter for Precision Pressure Gage
All Pressure Capsules

For use in applications where the gas is slightly contaminated with foreign bodies, Filter is capable of filtering bodies as small as 60 microns without introducing a measurable pressure drop. Can be installed on bourdon tube port, capsule port or both. Filter extends the overall height of the bourdon tube by approximately 4 inches.

NUPRO Type 4FR-SS, Filter Element 8-60

Installed on Bourdon tube capsule\$ 68.00

Additional filter element\$ 4.80

AFD - Air Filter - Heavy Duty for Precision
Pressure Gage and/or Precision Pressure
Controller

For use in application when the gas being used is heavily contaminated with oil and foreign bodies and pressure is less than 200 PSI; in use the AFD filter is installed in the line before the AF filter described above or in the input pressure line between the precision pressure controller and the pressure source. Type AFD filters have a removable, cleanable fluid collecting cup. Filter is designed to be used separately from the gage or controller and therefore requires some independent location.

SCHRADER Airline Filter-Type 3332M
1/4" NPT Ports, 1/2 Pint Bowl Capacity.

Price\$ 123.00

Gage Calibration - Additional Points

Each quartz Bourdon tube element is delivered with a 20 point, .015% NBS traceable dead weight tester calibration chart. Calibration points are evenly spaced between 5 PSI (lowest accurate operating point on dead weight tester pressure standard), and maximum rated pressure. At pressure lower than 5PSI, absolute accuracy is .002 in Hg.

Customer may specify any number of additional points, anywhere within these ranges as an optional extra.

Price per point\$ 10.00

Calibration below 31" Hg may be made against either a Dead Weight Tester or Standard Manometer.

Calibration below 4" Mercury may be made with a Dual Cistern Standard Manometer.

PRECISION PRESSURE CONTROLLERS

Model LPC - 100 Servo Low Pressure Controller

Shipping Weight - 25 lbs

For 110 Volts, 60 cps operation	\$1,760.00
For 220V-110V, 50 cps operation	\$1,760.00

Precision Calibration Controller System

(Manual Adjustment)

Model PCS - 100 Output pressure range 0 - 100 PSIA

Model PCS - 500 Output pressure range 0 - 500 PSIA

Price	\$ 763.00
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HIGH TEMPERATURE PRESSURE MEASURING SYSTEM

Any one of the following components may be purchased separately.

High Temperature Systems require Bourdon tube capsule Type 5 or 7 in any of the listed pressure ranges and any or all of the following:

Furnace for High - Temperature "Pressure Galvanometer"

Electrically heated furnace capable
of 1000°F, and consumes 1200 watts.
Shipping Weight - 20 lbs

Price	\$ 290.00
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Photocell Nulling Assembly for High - Temperature "Pressure Galvanometer" - Installed on the above furnace.

Contains 6 volt light source, pair of match photocell, optics (adjustable) and external transformer regulated light source power supply. Output of photocell can be monitored with an external microammeter, D.V.M. or recorder, or can be used to provide an error signal for automatic adjustment of the restoring pressure.
Shipping Weight - 2 lbs

Price	\$ 290.00
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